Meigs (J. A.)

CORRELATION OF THE PHYSICAL AND VITAL FORCES.

AN

INAUGURAL ADDRESS

INTRODUCTORY TO THE COURSE

ON

INSTITUTES OF MEDICINE

IN THE

Jefferson Medical College.

DELIVERED OCTOBER 12, 1868,

BY

J. ~~AITKEN~~ MEIGS, M. D.

PROFESSOR OF THE INSTITUTES OF MEDICINE AND MEDICAL JURISPRUDENCE,

ONE OF THE PHYSICIANS TO THE PENNSYLVANIA HOSPITAL, ETC.

L'empirisme peut servir à accumuler les faits, mais il ne saurait jamais édifier la science. L'expérimentateur qui ne sait point ce qu'il cherche ne comprend pas ce qu'il trouve. La physiologie générale ne se constituera définitivement que lorsque sa direction sera déterminée d'une manière rationelle par une conception claire du problème qu'elle se propose de résoudre. C'est pourquoi, après avoir examiné l'évolution des faits et resumé les découvertes et les travaux de la physiologie française pendant ce dernier quart de siècle, il importe d'indiquer aussi la marche de la science en signalant la tendance des idées et des théories dans l'investigation physiologique expérimentale."—CLAUDE BERNARD.

PUBLISHED BY THE CLASS.

PHILADELPHIA:

OFFICE OF THE MEDICAL AND SURGICAL REPORTER,

115 SOUTH SEVENTH STREET.

1868.

CORRELATION OF THE PHYSICAL AND VITAL FORCES.

AN

INAUGURAL ADDRESS

INTRODUCTORY TO THE COURSE

ON

INSTITUTES OF MEDICINE

IN THE

Jefferson Medical College.

DELIVERED OCTOBER 12, 1868,

BY

J. AITKEN MEIGS, M. D.

PROFESSOR OF THE INSTITUTES OF MEDICINE AND MEDICAL JURISPRUDENCE,

ONE OF THE PHYSICIANS TO THE PENNSYLVANIA HOSPITAL, ETC.

L'empirisme peut servir à accumuler les faits, mais il ne saurait jamais édifier la science. L'expérimentateur qui ne sait point ce qu'il cherche ne comprend pas ce qu'il trouve. La physiologie générale ne se constituera définitivement que lorsque sa direction sera déterminée d'une manière rationelle par une conception claire du problème qu'elle se propose de résoudre. C'est pourquoi, après avoir examiné l'évolution des faits et résumé les découvertes et les travaux de la physiologie française pendant ce dernier quart de siècle, il importe d'indiquer aussi la marche de la science en signalant la tendance des idées et des théories dans l'investigation physiologique expérimentale."—CLAUDE BERNARD.

PUBLISHED BY THE CLASS.

PHILADELPHIA:

OFFICE OF MEDICAL AND SURGICAL REPORTER,

115 SOUTH SEVENTH STREET.

1868.

JEFFERSON MEDICAL COLLEGE.
Tuesday, October 13th, 1868.

At a meeting of the Students of the College, held this day, it was unanimously

Resolved, That a Committee consisting of one member of the Class, from each State, Province, and Nationality, be appointed to wait upon Professor Meigs, and, in the name of the Class, express to him the assurance of its highest consideration, and bear him sincere thanks for the delight, as well as profit afforded us by his Introductory Address on Monday night, and that he be solicited to grant the manuscript for publication.

J. W. Heulings, *President*.

Jas. E. Shellenberger, *Secretary*.

Professor J. Aitken Meigs:

Dear Sir—In pursuance of the above Resolution, the undersigned Committee take great pleasure in discharging the duty therein imposed, in expressing to you, on behalf of the Class, its appreciation of your excellent Introductory on Monday night, and we respectfully ask the favor of the manuscript for publicatlon.

We also take this opportunity to say that, while it was with regret that we learned of the resignation of Professor Dunglison, your distinguished predecessor, yet we rejoice in the knowledge that his place is filled by one so capable of reflecting credit on the College, and benefitting ourselves and the students who come after us, and congratulate you upon obtaining such well-merited reward for your earnest investigations in Medical Science.

Very respectfully yours,

T. C. HAMMOND, Mo.
THOMAS SHRINER, Pa.
J. Y. PORTER, Fla.
HERMANN W. NEWCOMBE, Ky.
E. M. SMALL, Me.
J. F. LEWIS, M.D., Wis.
CHARLES M. GILL, N. J.
L. H. LAW, Ct.
H. OSGOOD, Mass.
EDWARD YATES, N. Y.
W. C. IRBY, S. Ca.
E. F. VOSE, R. I.
M. TREVENO, Mexico.
A. CUSHMAN, Indiana.
A. W. CALHOUN, Geo.
ROBERT HUGHES, Ills.
G. W. COPELAND, Nova Scotia.
E. G. PRIME, Vt.
J. S. RANDLE, Miss.
A. F. BELO, N. Ca.
BENJAMIN MYERS, Ohio.
EUGENE WILEY, Del.
FLETCHER DRUMMOND, Va.
A. G. ORR, Tenn.
C. O. WELLER, Texas.
JOSEPH STRAWN, Cal.
G. PAUL JONES, Md.
S. W. TAYLOR, Ala.

Philadelphia, October 15th, 1868.
No. 423 S. Broad St.

Gentlemen:

In compliance with the polite request contained in your very complimentary note of the 13th inst., I place at your disposal the manuscript of my Inaugural Address. Accept my acknowledgment of the honor thus conferred upon me, and while conveying to the members of the Class the expression of my high regard and esteem, say to them, also, that my earnest desire is to render my instruction both acceptable and profitable, and by a faithful and conscientious discharge of duty, to perform my part in sustaining our *Alma Mater*.

Very respectfully,
Your Friend and Obedient Servant,
JAMES AITKEN MEIGS.

To Messrs. T. C. Hammond, Thomas Shriner, J. Y. Porter,
Hermann W. Newcombe, E. M. Small,
and others of the Committee.

INAUGURAL ADDRESS.

GENTLEMEN:

Over all the land sickness, suffering and sorrow are daily and hourly supplicating the aid of the skilful physician. In the city and in the country fever is momently drying up the ruddy streams of human life. From the beggar's miserable hut, from the comfortable homestead of the industrious mechanic, from the towering palace of the millionaire, goes up the cry of pain, from men and women, and from children, too, alike by day and night. At this very moment in the streets and alleys of the great city, in the quiet places of the country, on the broad prairie and in the depths of the forest, women are travailing in the bitter anguish of child-birth; at this very moment, also, on the broad prairie and in the wild woods, in the quietude of the country and amidst the bustle of the city, men and women in the agony of the last hour are speeding away from the familiar scenes of their daily hopes and fears, speeding away they know not, and it may be, reck not whither. By various roads they pass away,—by fever, inflammation and plague: by dropsy, hemorrhage, palsy and a host of other ills; for the avenues of death are many indeed; and the grim monarch, never resting, never sleeping, sits enthroned in the focus of these roads and laughs in triumph as one by one the sons of men come forward and lay at his bony feet the tribute of their lives.

Filled with wonder at this constantly recurring spectacle, and actuated, perhaps, by a noble philanthropy, you have come up to this city from all parts of our common country to learn, if possible, why it is and how it is that men from the earliest recorded time have sickened and died; why and how it is that men still sicken and die. These questions you ask with the ulterior view of pro-

pounding still another. You are anxious to learn how to cure the sick, how to palliate human suffering, how to prolong life, how in short, to oppose successfully the machinations of the merciless death. In the glow of youth, with hearts full of hope and benevolence, and as yet unseared by the deceit and ingratitude of man, you have come up to this medical metropolis resolved to have your queries answered, your doubts solved, your earnest longings satisfied; resolved to obtain that knowledge which will make you the fast friend and brother of every sick man, and which will enable you, when you meet with such an one struggling with disease and death, to say to him as the Gipsey maiden in the forest dingle, said to the fainting Lavengro, when unutterable heaviness of heart had come over him, "Never heed, never fear; I will stand by you."

Standing in your presence to take my part for the first time, in conducting your medical education, as a teacher of an important and intricate branch of science, I feel at this moment most acutely the responsibility of my position. The Honorable Board of Trustees of Jefferson Medical College, after long and careful deliberation, confided to my care, in June last, the Chair of Institutes of Medicine and Medical Jurisprudence in this Institution. This trust I have accepted with mingled feelings of pleasure and uneasiness difficult to describe. The fever of exultation naturally consequent upon the labors and aspirations of years being at last crowned with success, is tempered with the keen wind of anxiety springing up from the contemplation of the severe standard of excellence by which my efforts are to be tried. The medical, scientific and literary reputation of Professor ROBLEY DUNGLISON, my predecessor, is world-wide. This colossal reputation combined with an extraordinary executive ability has done much,—very much,—as you all know, to place this college upon the proud eminence which for so many years it has enjoyed. Many of the shining lights which adorn the profession of medicine in this country and in other parts of the world have drawn their earliest knowledge of the healing art from Dr. Dunglison's written and oral instructions. His busy pen has done much to fashion medical opinion in this country. The last thirty-two years of his conspicuously honorable and useful life, during which he has been connected with this Institution, constitute an important chapter in the history of American medicine. His numerous and able works are in the library of every physician. Everywhere his opinions

carry with them an authoritative weight. In view of these facts you will not be surprised when I declare that I approach the field rendered illustrious by his labors, with becoming diffidence and humility. Only a few years ago I sat where you are now sitting, and listened to the words of wisdom which fell from his lips, listened with delight to his eloquent and masterly exposition of the Philosophy of Medicine. My intellectual being still vibrates with the enthusiasm with which he inspired me at that time for the study of Physiology. If, therefore, I play the part of the apologist, and crave your indulgence for my short-comings, may I not hope that this enthusiasm will enable me to meet all the demands made upon me, and that, though absent in person, the spirit of the Master may yet be with the Pupil and the College? And will you not for a moment join me in a fervent prayer to the Great Physician to stretch out the hand of healing, and so assuage the suffering of the Master?

Indeed, gentlemen, though I come to you surrounded with the distracting cares of a busy practice whose "sore task" not only "doth not divide the Sunday from the week," but "makes the night joint-laborer with the day," I nevertheless take heart of grace from the fact that I come to you not only with a lively appreciation of your difficulties as students, and with a clear conception of what you need to make you useful practitioners of medicine, but also with the practical experience acquired, several years ago, in two other medical schools. How long, how laborious, and how earnest was my preparation in these schools my former colleagues, several of whom still occupy important positions as teachers of medicine, and some of whom have honored me with their presence to-night, can best testify.

And now as I question myself how I can best occupy this hour, the words with which Hippocrates opens his Aphorisms, fall admonishingly upon my ear. "Life is short," said the sage of Cos, "the art long, the occasion fleeting." Constrained by these solemn and warning words of the Father of Medicine to turn aside from the trite congratulations and rhetorical display to which custom has somewhat unwisely devoted the introductory hour, I simply assure you of the sincere pleasure with which I greet your presence here to-night, and proceed, at once, to throw widely open the gate of entrance into the rich and varied domain of Physiology. Anxious to leave in your minds

some substantial memento of the time and place,—a memento which shall outlive, if possible, the "fleeting occasion,"—I propose to discourse to you, without further preliminary, upon certain historical points connected with the great doctrine of the Correlation of the Physical and Vital Forces, at present so strongly attracting the attention of the scientific world, and by so doing, to redeem a promise made to one who now slumbers in his lonely grave by the moaning sea, and who, during the latter years of his life, was to me both friend and teacher.

It was in the grim, mid-winter, fourteen years ago. All day long with never a pause, the snow had fallen rapidly, and the dreary midnight found me trudging laboriously homeward from the couch of a dying friend and patient. Long and anxiously had I striven, but in vain, to rescue the sufferer from his doom. As I toiled on amidst the deep-lying snow, with muffled body bent against the chilling blast, I asked myself again and again the question, Why is this man dying? What is the secret of this mystery called death? In rapid succession all the scholastic definitions of life and death flitted through my mind, but upon none of them could I rest with satisfaction.

Thus mentally occupied I found myself in front of the residence of one whose conversation had for me at all times a deep and abiding attraction. Knowing how late into the night his studies were habitually prolonged, I rang without hesitation and was promptly admitted. I found him alone, this "immortal heretic" in science, as that eminent physiologist, Dr. B. W. Richardson, of London, has recently styled him. On the table, on the chairs, in every available spot, books and manuscript were profusely scattered, while over all, the blazing fire in the grate cast a genial glow. The cold without, the books, the cheerful fire and the quiet within, strongly invited to study and contemplation. I detailed to him the symptoms of my patient, and sought his aid in interpreting this riddle of death. Earnestly we conversed together long past the "dead waist and middle of the night." So long, said he, in the course of this conversation, so long as the present doctrine of a vital force, peculiar and unlike any other force in nature, prevails, so long will this riddle remain unsolved, so long will we stand in the presence of this Sphinx, confounded and amazed, so long will the phenomana of life, disease and death remain for the physiologist, the pathologist and physician, a series of facts without co-ordination and

without harmony. Upon this topic he dwelt with glowing language, and though he complained of the neglect which his labors had experienced, he expressed his confident belief that the time would come when his opinions would find powerful advocates among the scientific men of the future. So I left him in the leaden-grey dawn of the winter morning, with the promise, that should a fitting opportunity ever offer itself, I would endeavor to give to his views their due place upon the historical record. Singularly enough, this opportunity occurs at the very time that the illustrious British physiologist, just referred to, is advocating these views with his powerful pen, and illustrating them by means of well-devised experiments.

In the latter part of the 18th, and the first half of the present century, physiologists, with but few exceptions, contended for the existence of a vital or peculiar governing principle or power in organic beings as the fundamental cause of growth, nutrition and all the other phenomena of life. This was the teaching of the celebrated surgeon-naturalist, John Hunter, in Great Britain, of the illustrious physicist, Alexander Von Humboldt, in Germany, and of that equally renowned anatomist, Xavier Bichat, in France. Hunter, in his "Lectures on the Principles of Surgery," delivered in 1786–7, declared emphatically that "animal and vegetable substances differ from common matter in having a power superadded, totally different from any other known property of matter, and out of which arise various new properties." Humboldt, in 1793, in his "Aphorismi ex Doctrina Physiologiæ Chemicæ Plantarum," defined the vital force as the "unknown cause which prevents the elements from following their original attractive forces;" and Bichat went so far as to assert in his "Anatomie Générale," published in 1801, that the physical sciences instead of being accessory are wholly foreign to physiology. As late as 1841, in the second edition of his "Principles of General and Comparative Physiology," and again in 1842, in the first edition of his "Principles of Human Physiology," Dr. Carpenter, for so many years the acknowledged exponent of physiological science in Great Britain, taught that "all the actions manifested by living beings are dependent upon two sets of conditions—an organized structure, possessed of certain properties which are termed *vital*, as being distinct from the physical properties of inorganic matter, and certain

agents, whose presence is necessary to call these properties into operation, and thus to produce the manifestations of life."

Upon this side of the Atlantic, after showing that Andral, Liebig, Roget, Müller, Tiedeman and others, all more or less decidedly advocated this view, Dr. Martyn Paine, the veteran Professor of the Institutes of Medicine in the University of New York, declared that "there is not, indeed, in the whole range of medical literature, one author, however devoted to the physical and chemical views of life, who does not evince the necessity of admitting a governing vital principle as a distinct entity, distinct from all other things in nature. I say there cannot be produced one author of any consideration who does not summon to the aid of his discussion a vital principle whenever he touches upon the abstract phenomena of life."

While these views were being inculcated by those in authority at the various centres of medical learning in Europe and this country, in his lonely garret in London, amidst privation, suffering and penury, cheerfully endured that he might avail himself of the facilities for study and investigation afforded by the libraries of the British metropolis, this friend and teacher, into whose study I intruded so abruptly on the winter night referred to, was slowly composing with much toil and patience a learned work in two volumes.

This work, which appeared in 1843, under the title of "Caloric, its Mechanical, Chemical and Vital Agencies in the Phenomena of Nature," was not, as I have elsewhere said,* so much one of original research as of original reflection and extraordinary generalization; though it did not add one new fact to the sum of human knowledge, yet it embodied the results of the most laborious and protracted thought applied to the examination of all the leading and well-established facts of physical, chemical and physiological science, with the view to harmonize such facts, to show their true relations, and to deduce from these relations a great system of natural philosophy, physiology, pathology and therapeutics—a comprehensive, philosophical theory, in short, of the universe.

Though lauded in the highest terms by the Editor of the *London Medical Gazette*, by Dr. Willis the translator of Wagner's Physiology, by the translator of Dumas and Boussingault's Organic Chem-

* North American Medico-Chirurgical Review for September, 1858, p. 812.

istry, and by other European writers, and though eulogized most enthusiastically by Drs. Caldwell, Condie and others in this country, the work made, nevertheless, so little impression upon the scientific public that it may be said to have fallen almost still-born from the press. Its conclusions were regarded with incredulity, and consequently, like all premature generalizations in science, were accepted by none. Indeed Dr. Carpenter in 1844, spoke of the author as an enthusiast and system-maker, and declared that his views were very unphilosophical. And yet, six years later Dr. Carpenter essentially accepted this physiological doctrine and advocated it with much force in a paper "On the Mutual Relations of the Vital and Physical Forces," read defore the Royal Society of London, in June 1850. And now, after the lapse of nearly a quarter of a century, we find Dr. Richardson, undoubtedly at present the foremost experimental Physiologist in Great Britain, contributing an article to the *Popular Science Review* for July 1866, on "Sun Force and Earth Force," in which the forgotten American author and his neglected work find at once an able champion and eulogist. "Attempts have been made," says he, "to demonstrate that sun force and earth force are the same, and that in using two terms we are only recording first impressions of natural phenomena; describing in words of a simple kind that which seems to be rather than that which is. Lord Bacon would appear to have had some such thought as this in view, when he gave utterance to the singularly beautiful sentence that 'heat and cold are the two hands of nature.' But the philosopher who first boldly asserted the unity of the two forces was a man much less known, though certainly not less learned than the great Lord Chancellor—I mean a man of our own time, and but recently dead—one Samuel Metcalfe."

Dr. S. L. Metcalfe, formerly of Kentucky, was for some years previous to his death, a resident of this city, (Philadelphia.) For several years he was my neighbor and friend, with whom I was at all times happy to commune upon matters touching the science of life, and it became my painful duty at last, to announce to the world, through the medium of the public papers, the news of his death, transmitted to me by telegraph, on the 17th of July, 1856, about a week after he had left the city at my request, in the vain hope of being invigorated and restored to health by the sea-breezes of Cape Island.

In his remarkable work upon "Caloric" he emphatically main-

tains the existence of a substantive vital principle not distinct from all other things in nature, but, on the contrary, identical with the *essentia caloris;* the *ουσια αιθερος*, or subtle fiery ether, which Pythagoras regarded as the "principle of life, animating the whole system of nature;" which Heraclitus held to be the "primordial principle of the generation of all things;" which Plato taught "to be the immediate natural agent, or animal spirit, to cherish, to warm, to enlighten, to vegetate, to produce digestion, circulation, secretion and organic motion in all living bodies, animal and vegetable;" which Hippocrates speaks of as the "cause of motion, change, growth, diminution, etc.," and to which Newton was inclined to ascribe far more efficiency as a primal and powerful causative agent than his biographers and critics appear to be willing to admit.

"The prevalent doctrine of modern physiologists, that the phenomena of life are wholly distinct from those of inorganic matter," wrote Dr. Metcalfe, "has arisen from our imperfect knowledge in regard to the primary physical cause of motion throughout nature; and is refuted by the fact that the organizing power of the earth, like all the mechanical and chemical transformations that modify its surface, is directly in proportion to the quantity of caloric which it receives from the sun. (p. 507.) That the power of living bodies to renew their composition by assimilation, and to reproduce their species by generation, is governed by the emphatic agency of caloric, is evident from the fact that the power of nature to multiply organic forms is directly in proportion to the temperature of the earth, from the equator to the polar circles. (p. 530.) Having shown this I proceed to prove that the organizing power of animals, and the activity of their respective functions, are directly in proportion to the quantity of the same active principle derived from the atmosphere by respiration." (p. 561.)

With wonderful precision and skill, Dr. Metcalfe heaped fact upon fact to prove that caloric intimately combined with, and acting through, organic matter as a peculiar medium, is the cause of all the complex phenomena of life; is in fact converted into the vital principle.

The leading views promulgated in "Caloric," were first announced to the world by Dr. Metcalfe, in an Essay entitled a "New Theory of Terrestrial Magnetism," read before the New

York Lyceum and published in 1833. From this monograph I quote the following paragraphs, which show how far his active mind had anticipated both Grove and Carpenter in their speculations concerning the convertibility of the physical forces into each other, and the correlation of these with the vital forces.

"It will be our first object in this Essay, to trace some of the most striking analogies of caloric and electricity; to show that they are radically the same subtle, imponderable and all-pervading element; and that its unequal distribution throughout nature, is the cause of all the various powers and attractions of ponderable matter with which we are acquainted. (p. 7.) . . . . . . It (caloric) is the source of life and motion throughout creation. (p. 8.) . . . . . We are not authorized to predict a primary distinction (between caloric and electricity) until fully acquainted with all the different states and affections of caloric under different circumstances; for example, in its combinations with different substances, in a solid, fluid, gàseous, or imponderable state—as with the matter of light—its diffusion, concentration, compression, &c. (p. 15.) . . . . . There is not a greater apparent difference between any of the forms of caloric and electricity, than between the electricity in the atmosphere and in an exhausted receiver. (pp. 15, 16.) . . . . . Before caloric combines with, and expands water into atmospheric vapor, it is universally acknowledged to be sensible heat; after it enters into the water and converts it into transparent, invisible vapor, its state is changed; and, when greatly accumulated in this state, it exhibits electrical phenomena. To say, however, that its elementary nature is changed, would be as unphilosophical as to contend that the latent caloric of water is specifically different in its nature from the same caloric when set at liberty by pouring water on calcined lime; or that it is distinct from the caloric which moves a steam engine by its expansion; or that the galvanic fluid is distinct from the electricity of a Leyden jar, because it moves with less velocity. (p. 16.) . . . . . Had philosophers attended more carefully to the great changes which take place in the states of caloric, produced by its various *modes* of combination with other matter in different forms, they would probably have been led to discover more clearly, if not the identity of caloric and electricity, at least that they are inseparable, and that without caloric there could be no electricity. (p. 17.) . . . . . One of the most decisive proofs that caloric and electricity are convertible into each other is, that

during all condensation of aerial vapor, whether into rain or snow, during winter or summer, caloric is given out in very large quantities. (p. 19.) . . . . . Caloric, electricity and galvanism have hitherto constituted a separate and distinct triad of imponderables, perfectly incomprehensible; all the phenomena of which are quite intelligible, if we refer them to the agency of one grand, primary, universal element. (p. 27.) . . . . . That there is a subtle, vivifying principle disseminated throughout nature, and which is intimately connected with caloric, would appear from the effect of cold upon the various tribes of animal and vegetable existence. (p. 46.) . . . . . . One thing is certain, that innumerable forms of life spring from, or at least accompany the presence of caloric; while its absence is always attended by the entire extinction of life. Hence it would appear unphilosophical to call in the aid of some other unknown imponderable aura as a vital principle, when the agency of caloric, united (though we know not precisely in what manner) to the various forms and combinations of matter, explains the phenomena quite as well. (p. 48.) . . . . . . The states and affections of caloric are infinitely diversified by the various modes of its combination with ponderable matter. (p. 49.) Does not caloric answer to the subtle ether of Sir Isaac Newton? Does it not extend from the centre to the circumference of the universe? Is it not the cause of all the motions and transmutations of terrestrial matter? of decomposition and recombination? of secretion, nutrition, growth, &c.? Is it not the semperviving energy of universal nature?" (p. 52.)

These passages I have selected at random, from the first part of Dr. Metcalfe's essay, not for the purpose of claiming for him the merit of originality in the enunciation of the doctrine of the correlation of the physical forces; for this, as will be presently seen, we cannot accord to him; but to show that in 1833 he was not only familiar with the great doctrine in question, but contended forcibly for it in the essay referred to, in which you will find not a few of the arguments employed by Prof. Grove, thirteen years afterwards, to substantiate the same great generalization.

The history of science viewed comprehensively and from an elevated stand-point, is seen to be the record of a definite intellectual progress, in which great discoveries are not so much the results of the inspiration of particular individuals, as of the labors of many observers and thinkers whose minds have been simulta-

neously occupied with similar ideas, and have unconsciously been directed, therefore, towards the same great object. The fact that remarkable discoveries are often made simultaneously by independent inquirers in different parts of the world, is in itself the proof that these discoveries are, in truth, the characteristic outgrowth of the intellectual condition of the epoch or era in which they were achieved. After a long preparation, when the age is at last ripe for it, the discovery is announced by one or more observers who thus become the mouth-piece of their time. Thus it was that the differential calculus was independently discovered by Newton and Leibnitz after prolonged attempts upon the part of scientific men to apply systematically the higher mathematics to general physics; thus it happened, too, that Priestly and Scheele simultaneously discovered oxygen, and Cavendish and Watt demonstrated the composition of water, after questions of molecular physics and chemistry had long been discussed by different observers.

In like manner the close of the last and the early part of the present century were characterized by an extraordinary intellectual activity manifesting itself in three channels of scientific inquiry which are evidently converging towards the discovery of some fundamental law or principle in physiology.

The scientific tendencies of the last fifty years have unconsciously and gradually led to the creation of a new philosophy of the forces, the application of physics and organic chemistry to the explanation of the functions of animals and plants, and the establishment of a remarkable structural theory of organization.

The observers in these different but related fields of inquiry have been advancing, like the central and lateral columns of a besieging army, to the attack of a stronghold of the precise locality, strength and means of resistance of which they have been in doubt. Foremost in the first of these columns or lines of scientific progress we find Franklin in 1749 demonstrating the identity of lightning and common electricity; Benjamin Thompson, of Massachusetts, afterwards Count Rumford, announcing to the Royal Society, in 1798, his conviction that heat was a mode of motion; and Sir Humphrey Davy, in 1812, in a work upon "Chemical Philosophy," maintaining that the "laws of the communication of heat are precisely the same as those of the communication of motion." In 1824, Carnot, a Frenchman, endeavored to demonstrate the condi-

tions under which heat could be converted into mechanical work. In 1827, Lardner Vanuxem published in Philadelphia "An Essay on the Ultimate Principles of Chemistry, Natural Philosophy and Physiology," on page 28 of which you will find the following clear and unmistakable proposition, the last of five conclusions which the author states to be "in conformity with the facts presented by chemistry and natural philosophy," and which he supports with abundant argument, and in a masterly manner.

"There exists but one kind of repulsive matter as will be shown, exhibiting four different states convertible into each other, not only accordingly as it is acted upon by particles, or groups of particles, forming masses, but according to the kind of particles and masses. These states of repulsive matter are caloric, light, electricity, and magnetism."

And again, on page 30, he says: "As all our experiments prove that caloric, electricity, magnetism, and light are convertible one into another, according to the relationships or quantities of repellant and attractive matter, it seems to me that their existence as four distinct fluids, or kinds of etherial matter, is inadmissible; for this conversion, or change of characters, is analogous to what are called the properties of bodies, and not to the bodies themselves."

Thus, then, in this city, forty-one years ago, by an experimental chemist, who was one of the early members of the Academy of Natural Sciences, was the doctrine of the correlation of the physical forces maintained; not as a shrewd and happy guess, not as a crude conception, but clearly and distinctly as a theory issuing from and harmonizing a series of well-established facts in physics and chemistry.

In 1833, Dr. Metcalfe maintained, as we have just seen, not only the convertibility of the physical forces into each other, but also the transformation of caloric into vital force. In 1837, Dr. Samuel Jackson, formerly Professor of the Institutes of Medicine in the University of Pennsylvania, delivered and published an able Introductory Lecture, in which he said,

"Physical phenomena, according to the class they belong to, are referred to a few simple laws, as gravity, caloric, affinity, galvanism, electricity, magnetism; all of which, it can now be scarcely doubted, are modifications of one great force. The force producing physiological or organic phenomena may be no more than a modification of the same ruling power displaying its activity in organized matter."

In 1839, Seguin, in a work on the "Influence of Railroads," distinctly expressed his belief in the identity of heat and mechanical force, and gave a calculation of their equivalent relation. In 1842, Professor Grove, in a lecture delivered before the London Institution, declared that "light, heat, electricity, magnetism, motion and chemical affinity are all convertible material affections." In the same year, J. R. Mayer, of Heilbronn, in a paper on the "Forces of Inorganic Nature," asserted that the imponderables were forces at once indestructible and convertible; while Liebig, in his "Animal Chemistry," distinctly promulgated the doctrine that every production of motion by an animal involves a proportional disintegration of muscular substance. In 1843, Mr. Joule published an important article on the mechanical equivalent of heat. In the same year, Colding, a Dane, presented to the Academy of Copenhagen a memoir in which were described some experiments, instituted with the view of demonstrating the great law of the conservation of force. In this year also appeared Metcalfe's work on "Caloric," in which the fundamental views expressed ten years before in his Essay on Magnetism were more fully elaborated.

It is a singular fact that at this stage of the progress of inquiry upon this subject, an article appeared in the *British and Foreign Medical Review* for October, 1844, in which these views were spoken of as being untenable. This article is a review of Dr. Metcalfe's work, and for various reasons has been attributed to the pen of Dr. Carpenter. The writer of it "deems it very unphilosophical to assert, as Dr. Metcalfe does, that caloric is *the* efficient cause of the vital actions of living beings, since it is only one of several causes which must concur to produce the results in question." He expressly discountenances the attempt of Dr. Metcalfe to prove the identity of caloric and electricity, or rather, that they are modifications of the same universal element; and declares that, although their analogies are strong, their differences are "still stronger, requiring that, for the present at least, their phenomena should be referred to a distinct category."

In 1845, Prof. Faraday delivered his celebrated Bakerian Lecture, in which he said, "I have long held an opinion, almost amounting to conviction, in common, I believe, with many other lovers of natural knowledge, that the various forms under which the forces of matter are made manifest have one common origin; or, in other words, are so directly related and naturally dependent,

that they are convertible, as it were, one into another, and possess equivalents of power in their action. In modern times the proofs of their convertibility have been accumulated to a very considerable extent, and a commencement made of the determination of their equivalent forces."

In the same year Dr. Mayer published at Heilbronn a paper "On Organic Movement in its relation to Material Changes," in which he showed that all changes in the living organism, whether animal or vegetable, were produced by forces acting upon it from without; the changes in its own composition brought about by these external agencies, being the immediate source of the forces which are generated by it. In this year also Mr. Newport was led "by the close relation shown by Dr. Faraday to subsist between light and electricity, and by Matteucci between electricity and nervous power, and by the known dependence of most of the functions of the body on the latter, to consider light as the primary source of all vital and instinctive power, the degrees and variations of which, he suggested, may perhaps be referred to modifications of this influence on the special organization of each animal body."

In 1846, Prof. Grove published the first edition of his treatise on the "Correlation of the Physical Forces," in which he "seeks to establish that the various imponderable agencies, or the affections of matter which constitute the main objects of experimental physics, viz., heat, light, electricity, magnetism, chemical affinity, and motion, are all correlative, or have a reciprocal dependence; and that neither taken abstractedly, can be said to be the essential or proximate cause of the others, but that either may, as a force, produce or be convertible into the other; thus heat may mediately or immediately produce electricity, electricity may produce heat, and so of the rest." "I believe," he continues, "that the same principles and mode of reasoning might be applied to the organic, as well as the inorganic world, and that muscular force, animal and vegetable heat, &c., might, and at some time will be shown to have similar definite correlations."

In 1847, Helmholtz published an admirable monograph on the "Conservation of Force," and in the same year, in New Orleans, appeared a remarkable pamphlet from the pen of P. E. Trastour, entitled "Caloric, Origin, Matter and Law of the Universe."

In 1848, Dr. Carpenter contributed to the *British and Foreign*

Medico-Chirurgical Review for January, a review of Matteucci's "Lectures on the Physical Phenomena of Living Beings," in which he says "that the *vital* forces of various kinds bear the same relation to the several *physical* forces of the inorganic world, that they bear to each other; the great essential modification or transformation being effected by their passage, so to speak, through the germ of the organic structure, somewhat after the same fashion that heat becomes electricity when passed through certain mixtures of metals." In this year the "Identities of Light and Heat, of Caloric and Electricity," were ably advocated in a pamphlet bearing this title by my esteemed friend Dr. C. C. Cooper, of Philadelphia. In 1849, Dr. Fowler read before the British Association an excellent paper in which he discussed the probable correlation of vitality with the physical forces. In 1850, Matteucci communicated to the Royal Society some experiments which appeared to show that electricity and nervous force are correlated. In the same year, Dr. C. B. Radcliffe, since well-known for his researches upon epilepsy and muscular motion, in a work entitled, "Proteus, or a Law of Nature," endeavored to demonstrate the existence of a common idea or principle in nature, by referring not only to the material organisms of plants and animals, and the analogies which connect unorganized substances with living structures, but also to the unity of the forces which are operative in the organic and inorganic kingdoms. In this year also Dr. Carpenter published in the Philosophical Transactions of the Royal Society, the admirable paper already mentioned, in which he aimed to show that the general doctrine of the "Correlation of the Physical Forces" propounded by Mr. Grove, was equally applicable to those vital forces which must be assumed as the moving powers in the production of purely physiological phenomena; these forces being generated in living bodies by the transformation of the light, heat and chemical action supplied by the world around, and being given back to it again, either during their life, or after its cessation, chiefly in motion and heat, but also to a less degree in light and electricity. In 1851, Mayer, in a paper, entitled the "Mechanical Equivalent of Heat," announced the law that the heat produced mechanically by the organism must bear an invariable quantitative relation to the work or muscular exertion expended in producing it. In this year, also, Dr. Radcliffe, published an excellent treatise upon the "Philosophy of Vital Motion," and at the same period, Dr. J. H. Watters, the

present incumbent of the chair of Physiology in the Missouri Medical College, published at Philadelphia "An Essay on Organic or Life-Force;" in which he maintained that "life, or the actions of of an organism, are produced by forces which are evolved in the decomposition or decay of that organism." In 1854, Helmholtz delivered a lecture in Königsberg, on the "Interaction of Natural Forces," in which he said that "Nature, as a whole, possesses a store of force which cannot in any way be either increased or diminished; and that, therefore, the quantity of force in nature is just as eternal and unalterable as the quantity of matter."

In 1857, Prof. Joseph Henry, of the Smithsonian Institution, also directed attention to this subject in an article on "Meteorology in its Connection with Agriculture." In 1859, Prof. Leconte published an important memoir "On the Correlation of Physical, Chemical, and Vital Forces, and the Conservation of Force in Vital Phenomena," in which he attempts to demonstrate the reality of four planes of material existence rising successively in importance above each other. Elementary existence constitutes the lowest Chemical compounds (the mineral kingdom) form the second. The third plane is that of vegetable existence; the fourth and highest, that of animal existence. Matter, he thinks, can pass from the lowest to the highest plane only by degrees, and in consequence of a greater expenditure of force than is necessary to keep it in the plane of elementary existence. Any amount of matter returning to a lower plane by decomposition must set free or develope a force which may raise other matter from a lower to a higher condition. Thus, decomposition must in every case develope force, which force may take the form of heat as in combustion, or electricity as in electrolysis, or may expend itself in forming chemical compounds, or even in organizing matter. In the egg, during incubation, heat is indirectly transformed into a vital force causing decomposition of a part of the organic matter, which latter by descending from the organic to the mineral plane sets free a force which may raise the remaining portion into a slightly higher condition. In 1860 Dr. Richardson of London delivered a series of remarkable Lettsomian Lectures "On Certain of the Phenomena of Life," in which he maintained that in the animal body there is no arrangement for the generation or liberation of any variety of force except caloric; that this force set free in the combustion of the blood, is an active force in every structure; that caloric is the primary cause of

motion in nature, and is therefore a primary cause of life, in so far as motion represents life; that it possesses all the attributes by which the varying and yet universal properties of all matter are developed; that as a primary force it is the first and last in action, and universal in presence and production. "Limbs are flexible," says Dr. Richardson, "and movable at 96 degrees of heat. If this temperature be reduced a few degrees, the muscles become painfully contracted; if the reduction be made further, the muscles become rigid; but they are relaxed by gentle warmth, and the motion is restored.

"In the animal world, I see different animals of different degrees of motive power and endurance. Examining their construction, I find as an unvarying law that the strength or the power of motion is in exact relationship to the power of the animal to eliminate and apply caloric.

"I see an animal at rest, and I notice that he converts a certain weight of carbon into carbonic acid, and liberates a certain proportion of water. I see this animal in active motion—a horse galloping with his rider, every muscle in full action; and now he pours out a greater measure of carbonic acid, and volumes of visible vapor of water. Between the steam evolved by this animal and the steam evolved by a locomotive, will any one define to me the difference in relation to either cause or effect? I mean, of course, in relation to the physical differences; for, with the metaphysical I have nothing to do.

"In so far, then, as motion represents life, caloric is the source of living motion. It may undergo modifications in character; now being latent, now sensible; now being rapidly conducted through metals, or other couducting media; now rapidly evolved in series of concentrate sparks. We may call it in these varied forms by other names—electrical force, galvanic force—but it is the alpha and omega of them all—the principle of motion."

Dr. Richardson tells us that when these views were first enunciated by him they were based confessedly upon general inferences. Since then, he has subjected them to the test of rigid experiment, and believes them to be now firmly established. In the course of an article entitled, "Caloric the Form of Force in Nervous Matter," which was published in the *Medical Times and Gazette* for August 3d, 1867, as a part of a series of experimental lectures on the influence of extreme cold on nervous function, he says: "For

what are the facts which have here experimentally been brought to our notice? We have had before us a frog; we deprived it of all sensibility; we deprived it of all power of motion. How did we effect this? Simply and solely by the abstraction of the heat from its cerebro-spinal system. When the animal was thus reduced to inertia—when, to all appearance, it was dead—we saw its life fully restored. In what manner and under what condition did this restoration become pronounced? There was only one condition—restoration of caloric. When we put these two great facts together, and when we couple them with the further fact that the animal has no means for producing any force except calorific force, we cannot, I think, escape the conclusion, that animal force is caloric; with this we may admit—indeed we must admit—that other correlations, when brought to bear on the living body, can stir into temporary motion the organic structures; we must admit that light can set up motion from the eye to the brain; that the passage of an electric current can set up motion in muscle, and motion from any periphery of nerve to brain; that the vibration of air can convey motion by the ear to the sensorium, and that the motion of minute particles of organic matter may be communicated through the olfactory nerves back to the centres of those nerves. But these admissions do not interfere with the general truth that caloric is *the* force of life—that it is true, and sufficient to explain all the phenomena of living motion."

This language, uttered after mature deliberation, and after long and laborious experimental research; this language, pronounced in 1867 as the dictum of science by England's indefatigable physiologist, resounds in my ears like the echo of the simple but pregnant words with which Dr. Metcalfe addressed the New York Lyceum, in 1833.

In such generalized expressions culminates, at length, the long series of observations and experiments, so diversified in detail, so uniform in tendency, and so carefully conducted from the days of the great American printer, Benjamin Franklin, to the time of that illustrious son of the humble smith, Michael Faraday, whose ashes lie yet warmly in their recent grave.

Out of these observations and experiments has been evolved a new theory of the physical and vital forces. They have shown that force, like matter, is indestructible; that throughout nature there is an endless and never-resting force-mutation, each of the

different forces generating or being converted into the others in a ceaseless round; that the heat and light of the sun absorbed by the plant and stored up in its organic compounds, are transferred to the animal in digestion, and again liberated as motor, nervous, and, if the conclusion of Bain is to be accepted, as mental force in the decomposition of the muscles, nerves and brain, or in the oxidation of the blood supplied to these organs.

While these views were being developed another set of observers were and still are attempting to elucidate the organic functions by applying to them the methods of research which rule in Natural Philosophy and Chemistry.

Anterior to the time of Lavoisier, that is to say, in the first half of the last century, it was supposed by physiologists generally, that the manifestations of life took place independently of ordinary physico-chemical laws and were regulated by occult influences. Lavoisier, that noble victim of the guillotine, by creating modern chemistry, explained, at the same time, the nature of the chemical phenomena which take place in living beings. He showed clearly that life is maintained by chemical and physical phenomena which do not differ as to their cause from those which have their seat in inorganic bodies. He proved that animals in respiring, and metals in oxidizing, absorb from the air the same active or vital principle, oxygen and that the absence of respirable air arrests oxidation as well as respiration. Subsequently, in conjunction with Laplace, he announced that the development of heat in the living organism was a process in every respect analogous to the combustion which takes place in an ordinary fire. The labors of Lavoisier thus tended to remove the two organic functions—Respiration and Calorification—from the list of purely vital to that of chemical phenomena. In like manner, Magendie by his experiments on absorption in 1809, and on the elasticity of the arteries in 1817, demonstrated that the functions of Absorption and Circulation were due, if not wholly, at least in great part to physical forces. Bichat, the strenuous advocate of vitalism, had been dead but seven years, when Magendie first announced himself to the scientific world in a memoir strongly criticising the doctrine of the vital properties attributed by Bichat to the tissues; and it is a significant fact, that Magendie published a course of lectures delivered by him at the College of France, under the title of the "Physical Phenomena of Life."

Spallanzani, Reaumur, and Stevens in the last century, and Beaumont in 1825, instituted a series of elaborate experiments proving that gastric digestion is essentially a chemical process. Thus the first step was taken towards transferring the digestive act from the region of vital phenomena, a step which has since been verified for alimentary as well as gastric digestion. Beaumont's observations were published in 1833, and in that very year an eminently philosophical observer, Prof. J. W. Draper of New York, commenced a series of observations and experiments which were published in 1844 under the title of the "Forces which Produce the Organization of Plants." In this treatise, in which the existence of the vital force of physiologists—as a homogeneous and separate force—is uniformly denied, Professor Draper showed how organized bodies were produced by the action of the sunbeam; how the carbonization of water in the leaves by the light of the sun, caused the flow of the sap in plants; how the circulation in animals was produced by the oxidation of venous blood, on the one hand, and the deoxidation of arterial blood on the other; how the process of digestion in plants was governed by the yellow ray of the spectrum, &c.

Not only have respiration, circulation, the development of heat and electricity, digestion, absorption, and to a great extent, secretion, been shown to be due to physical and chemical processes; but it has become highly probable, in the recent progress of physiological science, that many of the actions of the nervous system, including the phenomena of the special senses, are the results of physical changes in the two kinds of nervous matter,—substances exceedingly prone to change, owing to their complex constitution and high equivalent number.

During the last forty years the labors of Wöhler, Pelouze, Kolbe, Wurtz, and especially Berthelot, have conclusively shown that numerous organic substances, hitherto considered the peculiar products of the living organism, can be built up in the laboratory from their chemical elements, by peculiar synthetical processes. So recently as December last, Wurtz announced that he had effected the synthesis of neurine; while Kolbe, at a late meeting of the Chemical Society, stated that he had obtained urea from carbonate of ammonia by heating the latter substance in sealed tubes to the temperature at which urea commences to decompose.

It is highly probable, indeed, that the time will come when all

the products of living organisms will be created or closely imitated by the chemist. The complete realization of this probability will strongly tend to deprive nutrition or assimilation of its mysterious vitalistic character, and bring it, in common with the other organic or vegetative functions, within the pale of physico-chemical actions.

Want of time alone prevents me from referring, even in the briefest manner, to the numerous observers who for many years past have been industriously engaged in bringing the exact sciences to the aid of physiology. Suffice it to say, that their efforts have done much to elevate this study from its former helpless and deplorable condition, and given to it a wonderful impetus by placing it securely upon the foundations of chemistry and natural philosophy. It is in fact, now commonly conceded that the general laws which govern the phenomena of living bodies, are identical with those which rule in the inanimate world, and that there is for both one common method of investigation. Vanuxem long ago declared that, "the ultimate laws or principles of physiology are the ultimate laws or principles of chemistry and natural philosophy." Lehman believes that, "the time will come, and is no longer distant, when the entire physiology of animal life will be resolved into physiological physics and physiological chemistry." Mulder thinks that "the same forces govern alike the animate and inanimate kingdoms." Schleiden even regards cell-formation itself as simply a chemical act; while Mr. Rainey in his memoir "On the mode of Formation of Shells of Animals, of Bone, and of several other Structures by a process of molecular Coalescence," comes to the conclusion that the growth of bone, and even of some of the soft tissues, may be explained on physical and chemical grounds alone. "Daily advances in science," says Dr. Gull, in his Hunterian oration, "make it more and more probable that organized beings are the necessary development of the physical conditions of our globe." At the meeting of the British Association, held at Nottingham, in 1866, Prof. Huxley, the President of the Biological Section, did not hesitate to say, in the course of his address, that the science of physiology was nothing more than applied chemistry and physics. Prof. Humphrey, of the University of Cambridge, has also quite recently placed upon record his conviction that "whatever be the law and forces which effect and regulate the evolution of species, they are probably of the same

kind as those which are operating in the inorganic world. The orderly and definite manner in which forms and features and specific characters are given and preserved in the one instance, may be assumed to be of the same nature as in the other; and we must probably refer the fixed animal and vegetable types to influences identical with or similar to those by which the forms are assigned to crystals, and the stratification is given to rocks, by which the geological epochs have been determined, and the boundaries of our planetary and solar system have been set." Claude Bernard, in his admirable "Rapport sur les Progrès et la marche de la Physiologie Générale en France," declares that physiology is not a natural science like geology, zoology or botany, but an experimental science like physics and chemistry. It is indeed the physico-chemical study of animal and vegetable bodies. He regards life in its physico-chemical aspect as only a modality of the general phenomena of nature. Borrowing its forces from the external world it engenders nothing, but only varies the manifestations of these forces in a thousand ways;—thus verifying the ancient idea that the human organism is a microcosm or little world reflecting in itself the macrocosm or universe.

The labors of the physico-chemical school of physiologists, conducted so vigorously during the last half century, have clearly shown, among other results, that there is for physiology a certainty in its kind as philosophical, though by no means as rigidly exact, as that which characterizes the mathematical sciences themselves. The demonstration of this certainty, however, depends upon the discovery of the great fundamental law or theory of physiology—a law related to the facts of this science, as gravity is to those of physics, as chemical affinity to those of chemistry, and as the correlation of forms is to those of comparative anatomy and palæontology. The history of medical philosophy is in great measure the record of numerous attempts to discover this law. These attempts are embodied in the doctrines of solidism, humoralism, vitalism, chemicism, which were crude speculations, ambitious but misguided generalizations, however, rather than philosophical utterances, and being without the assistance of philosophical anatomy, which had not yet been created, they necessarily failed to establish a correct theory of life. The formation of a positive and satisfactory theory of organization, sufficiently comprehensive to embrace all the forms of animal and vegetable life, must necessarily precede

the establishment of a true theory of life. A theory of structure, as simple as it is grand, has already been erected upon the labors of many zealous naturalists and physiologists, chief among whom are Cuvier, Bichat, and Schwann. Cuvier made the first decided step in this direction, by announcing, in 1795, that the study and classification of animals should be founded rather upon their internal organization than their external peculiarities. The establishment of this principle did much to transfer zoology from the hands of the mere observer of external characters to those of the anatomical investigator and experimenter. It substituted an exact and reliable method of classification for the artificial system bequeathed to the world by Linnæus. In physiology it paved the way for the solution of the great problem of the duplex life of man, and the connection of this life with organization, in so far as it rendered the laws of the correlation of forms and the subordination of parts available to physiology.

The next important step was made by Bichat, who investigated the human organism with the view of obtaining some clear and definite notion concerning the causes and nature of life. He sought to establish a theory of life by investigating the physical and chemical properties of the structural elements of the human body. He saw that something more was required than the mere comparison of organs. He saw in the labors of Carmichael Smyth, Bonn, Bordeu, and Fallopius, the germ of a great method, of a great instrument of research. With them he recognized the physiological value of the tissues; but his conception of this value was far greater, and more philosophical than theirs. With an industry almost unparalleled, he resolved all the organs of the body into twenty-one tissues, essentially distinct, but possessing in common the two great properties of extensibility and contractility. This was a great advance. To reduce these tissues to one primordial form—the cell—years of patient and laborious research were yet required by the lynx-eyed men of the microscope. The day in which Bichat lived was not prepared for this generalization. Great improvements in the microscope were required before further progress could be made. It was not, consequently, until so late as the early part of the present century, that the cell-theory took a definite form, and the labors of very many men were required to bring it to its present degree of development.

The doctrine of cell-genesis, the broadest generalization at

present known to statical physiology, began with Malpighi in the recognition of the blood-corpuscles as small globules, in the latter half of the seventeenth century, and received many of its early facts through the industry of Leuwenhoek, Hewson, and Haller, whose labors tended strongly to establish an individuality of organization unknown apparently to the ancients. Although that great and almost forgotten genius, Caspar Friedrich Wolff, had announced in his "Theoria Generationis," the first edition of which appeared in 1759, the fundamental features and many of the details of the present doctrine of the histological development of plants and animals from cells, it was not until 1816 that the great idea of the structural unity of the organic world began to take a definite shape in the minds of physiologists. It was in that year that Treviranus announced that all the tissues were reducible to three morphological elements—the amorphous, fibrous and globular. But this announcement, though regarded as remarkable for its correctness, and far in advance of the knowledge of that day, was afterwards shown not to be broad enough. The great work of Heusinger, which appeared six years afterwards, the discovery of the nucleus of the vegetable cell by Robert Brown, in 1833, the investigations of Purkinje and Deutsch upon cartilage-corpuscles, and the process of ossification, the researches of Valentin, in 1835, upon the formation of pigment-cells around pre-existing nuclei, and the comparison instituted by him between the cells of vegetable tissue and those of cartilage, the observations of Schultze upon the histology of the blood, and particularly upon the cell-relations of the blood-particles, the labors of Henle, Vogel, Donné, Boehm, and many others, and, finally, the announcement of the law of developmental unity for all vegetable cells made by Schleiden in his great work on phytogenesis, published in 1838, were all necessarily preliminary, not so much to the discovery as to the establishment of the cell-theory, as promulgated by Thomas Schwann, in 1839. This theory, modified in many of its details since the time of Schwann, is essentially one of structure and organization, and as such should be regarded as the indispensable forerunner of the true conception of the theory of life. Life, we can study only through or by means of its phenomena, and these are exhibited in their simplest and most easily recognized forms in the growth and development of the simple cell—the structural unit of the entire organized world. "The cell," writes Virchow, "is really the ultimate morphological element in which there is any

manifestation of life, and we must not transfer the real seat of action to any point beyond the cell."

All nutrition and secretion are accomplished by the cell; it is the agent in nervous and muscular action; by it are fabricated the special organic products of the living organism. It is the great physiological radical, and though it obeys the physico-chemical laws which rule in the inorganic world, it nevertheless differentiates the animal and plant, on the one hand, from the mineral kingdom, on the other, by its unique structure and the peculiar processes which take place within it. Bernard, with great propriety, insists upon the fact that epithelial, muscular, nervous, secreting and other cells are special tools or apparatus which cannot be created by the chemist and employed in his laboratory. Wanting these histological elements, these elementary organic instruments, these vital retorts and crucibles, the chemist cannot imitate the wonderful processes which are effected through these elements alone, and which constitute development, growth, nutrition, &c. Numerous organic products, both vegetable and animal, he can produce artificially by curious and complicated synthetical procedures, but these are not the processes by which nature works through her alembic, the secretory cell. Development, growth, nutrition and decay, the visible expressions of the activity of the self-multiplying and self-metamorphosing cell, though under the executive control of physico-chemical laws, are thus seen to be morphologically vital. But growth and development, philosophically viewed, are simply modes or varieties of organic motion—of that molecular motion ceaselessly taking place in the germinal matter and formed material of the ultimate structural element of the tissues, and leading to numerous differentiations of structure and form. The study of life, therefore, in its simplest and ultimate features, is the study of these differentiations of motion and form as influenced by the external or physical conditions of vitality. But these conditions are many, constantly varying in intensity, and the facts which we possess concerning them have long been accumulating. Out of these facts is now being developed the "correlation theory" already referred to—a theory bolder and more comprehensive by far than that of cell-genesis and strictly dynamical or biological in character—a theory which ambitiously seeks to resolve all the active, external conditions of life—the forces so-called—into one

universal force or principle—itself, perhaps, the essence or principle of life.

These two great theories of cyto-genesis and physico-vital correlation, the one structural, the other dynamical; the one explanatory of form and function, the other of the active, influencing cause of form and function, are beginning to be regarded by physiological thinkers as the two broad roads leading to a generalization more simple, more beautiful, and still more comprehensive than any with which biological science has yet been crowned.

Pressing on with industrious and philosophic zeal along the former of these two roads we find Remak, Virchow, Weber, Redfern, His, Bottcher, Billroth, Paget, Beale, Max Schultze, Robin and many others.

On the other highway of research leading to the true theory of life we encounter, among many others, Vanuxem, Metcalfe, Grove, Carpenter, Faraday, Mayer, Radcliffe, Hinton, Leconte, Vierordt, Donders, Fick and Wislicenus, Ranke, Tyndall, Frankland, Lawes and Gilbert, Parkes, Odling, the Rev. Dr. Haughton, Bence Jones, &c.

Intimately connected with the results arrived at by these inquirers, a new channel of research has lately been opened which promises to lead to remarkable results—which boldly and perhaps rashly promises to demonstrate, indeed, that life is an evolution, rather than a separate creation, and is thus essentially connected with the great life of the globe itself. This new line of inquiry was started by the discovery of Ascherson, that fat or oil-globules placed in an albuminous solution become coated with spherical envelopes of coagulated albumen. In this phenomenon Ascherson recognized a type of cell-formation. From the experiments of this observer, and from those of Wittich, Harting, Melsens, Panum and others, who have ably discussed this phenomenon as to its chemical or physical nature, and its relations to the progressive physical changes which take place in the chyle as it passes onwards through the lacteals into the thoracic duct, we learn that the globular form of the organic cell is that naturally assumed when oily and albuminous matters are brought into contact. Prof. Bennett, in an extraordinary lecture "On the Atmospheric Germ Theory and Origin of Infusoria," delivered before the Royal College of Surgeons, Edinburgh, in January of this year, asserts that the observations and experiments conducted by him for a number of years past, have

led him to the conclusion " that the vegetable and animal infusoria which we find in organic fluids during fermentation and putrefaction, orginate in oleo-albuminous molecules, which are formed in the fluids, and which, floating to the surface, constitute the primordial mucous layer of Burdach,—the proligerous pellicle of Pouchet."

In this connection must be recalled the fact long ago dwelt upon by both Vanuxem and Metcalfe, and recently so strongly insisted upon by Herbert Spencer, in his philosophical survey of the "Principles of Biology,"—the fact that oil and albumen consist of hydrogen, oxygen, nitrogen and carbon chiefly;—the most ethereal forms of matter, those, in other words, possessing the highest calorific condition and exhibiting the greatest degree of molecular mobility. In another place I have been at much pains to collect together numerous and striking facts which show that in the inorganic world variation in the atomic heat of a body is accompanied by variation in its crystalline form;* and Boutigny of Évreux, in his admirable work, "Études sur les Corps à l'État Sphéroïdal," the third edition of which appeared in 1857, details numerous experiments showing that certain inorganic substances may be made to assume the globular or spheroidal form by increasing artificially their calorific condition, or, in other words, by rendering their calorific state in a measure analogous to that which, owing to their peculiar material composition, naturally appertains to organic substances.

These facts, together with the observations and experiments of Graham upon the colloidal and crystalloidal forms of matter, of Beneke, Virchow, G. Liebreich, Neubauer, Baeyer, Koehler and others upon that remarkable substance myelin; of E. Montgomery and Bennett upon the artificial production of cell-forms in viscid plastic materials by imbibition—all point towards the realization of the opinion of Schwann, that " the formation of the elementary shapes of organisms is but a crystallization of substance capable of imbibition,"—an opinion in which he was anticipated, as in many other matters, by Caspar Wolff, who when but six and twenty years of age, had already announced to the world in his "Theory of Generation," the startling thesis of the structural identity of plants and animals.

* Essay on the Relation of Atomic Heat to Crystalline Form.—*Journal of the Academy of Natural Sciences.* Vol. III, part ii.

Such are the researches and such the tendencies, which, at present, characterize philosophical Biology, and which, with bold and impatient hand, are striving to thrust aside the veil of Isis covering the hieroglyphs of life.

A retrospective glance at the scientific progress of the last two hundred and seventy years shows us clearly that the glory of the seventeenth century was the development of the doctrine of universal gravitation and the establishment of the science of astronomy—a science treating of the motions and mutual relations of masses of matter; that the glory of the eighteenth century was the development of physics and chemistry, or those sciences which deal with the relations and reactions of atoms of matter; and that thus far the office of the nineteenth century, owing to the wonderful perfection to which the microscope and other instruments have been brought, has been the discovery of many of the laws upon which the mysterious phenomena of life depend. The great advance of our knowledge in histological and morphological development since the beginning of the present century, coupled with the new doctrine of the forces, has given rise to the growing conviction in the minds of physiologists that we are upon the eve of some great discovery in Biology, which will prove, in the hands of future physiologists, as powerful a means of research as has already been in those of the chemist, the law announced by Kirchoff in 1859, relative to spectral analysis. It may be that this discovery is to be reserved as the crowning glory of the coming century; it may happen, on the contrary, that some busy and ambitious brain, even now within hearing of my voice, is destined to grasp, in all their details, the facts at present in our possession, add to them still others, and suddenly, before the present century has run its course, utter to the world the formula by which they are colligated, and which expresses their true significance. In the present state of scientific progress and unrest who can tell?